ELEMENTS OF CARBURETION

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ELEMENTS OF CARBURETION

A THESIS

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MECHANICAL ENGINEERING

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The writers of this thesis wish to acknowledge their indebtedness to the Stromberg Motor Device Company, in whose laboratories the following tests were made; to Mr. Daniel Roesch for many valuable suggestions; and to Mrs. Julia Beveridge, librarian of the Armour Institute of Technology.

E. R. Burley, Jr.

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Introduction.

The general subject comprising the mechanical vaporization of hydrocarbons for use in internal combustion motors, is much deeper and more complicated than one would ever suppose from a cursory glance at the problem. Indeed it has often been said in testing laboratories and engineering departments that "no one knows anything about carburetion"; and this statement is true in that no accurate and precise laws have been formulated covering all of the action of the carburetor.

Many men have spent and are spending much time and study on this subject; so of course much has been learned and some day all will be known concerning this problem, but at the present time it is almost safe to say that the carburetor is still in the "cut and try" stage of its development.

The average oarburetor of today may be divided into the six following items:

1. A jet in which a constant level of gasoline is maintained.

2. A Venturi tube surrounding this jet.
3. An air opening below the jet.
4. A mixing chamber above the Venturi tube.
5. Some method of varying the proportion of fuel to air, which usually consists of a variable air opening, above the Venturi, controlled by the pressure drop.
6. A throttle for varying the amount of mixture fed to the engine.

Great variations of the above may be found in standard carburetors, but, in general, these cover the more successful types.

The object of this thesis, then, is to study these parts and determine what each adds to the whole in the way of power, flexibility, economy, or ability to accelerate.

In order to accomplish this result eight different carburetors were made and tested. In brief they were as follows:

A_1 Straight tube and two inch jet with gasoline level 5/8" below tip, one constant air opening below jet and at side of tube.

A_2 Straight tube and one and one half inch jet with gasoline level 1/8" below tip, one constant air opening directly below jet.

B The same in every way as A_2 except that a Venturi tube is placed around the jet.

C This is the same as B except that a spring-controlled air valve ~~control~~ governs most of the air admitted to the carburetor.

D The same in every way as B except that an extended Venturi tube is used and an auxiliary air valve is placed above the Venturi and controlled by a "low speed" spring.

E The same in every way as D except that the air valve is controlled by a "high speed" spring.

F This is the same carburetor as D but the "high speed" spring of E is added, thus producing the effect of both on the auxiliary air valve.

G This carburetor consists of a one and one half inch jet, a Venturi tube, an auxiliary air valve controlled by one spring, and a secondary nozzle placed in this passage and brought into action by the suction of the motor on this valve.

All of these carburetors were necessarily fitted with mixing chambers, throttles, and float chambers. The jets were of the constant opening type, a change in gasoline opening necessitated a change of jets. The nozzles were numbered according to the drill size of the openings.

Whenever adjustments were possible the carburetor was set with the desire of obtaining power, flexibility, economy and ability to accelerate. In this way the results are not especially good for any one adjustment. For instance, if a carburetor were set to give extreme economy, it would be found that the acceleration were woefully lacking. So all of the following results must be taken, not as the best for power or economy or flexibility obtainable, but as the results of a carburetor when set to give average service in an automobile.

The test of each carburetor consisted of determining the maximum and minimum speeds at which it would run an engine under load, the maximum horse-power obtainable with wide open throttle, and a number of economy runs. These tests were taken for each seting of the carburetor which was at all correct.

Discription of the Apparatus.

It is undeniable that a carburetor can be of use only when attached to a combustion motor and, since the action of the carburetor and motor are absolutely connected, the best and most practical method of comparing carburetors is to study the action of an engine when working with the different carburetors. It was therefore necessary that only one motor be used in all of the following tests.

It was attempted to keep the condition of this motor as nearly constant as possible, that is, the machine was kept well oiled, the adjustments tight, the spark-plugs clean, the jacket water about the same temperature, and practically the same quality of gasoline used thruout the tests.

The motor was of the four cylinder, four cycle type, built by the Buick Motor Car Company and rated by them as twenty horsepower. The cylinders were cast in pairs and had a bore and stroke of three and three quarters inches.

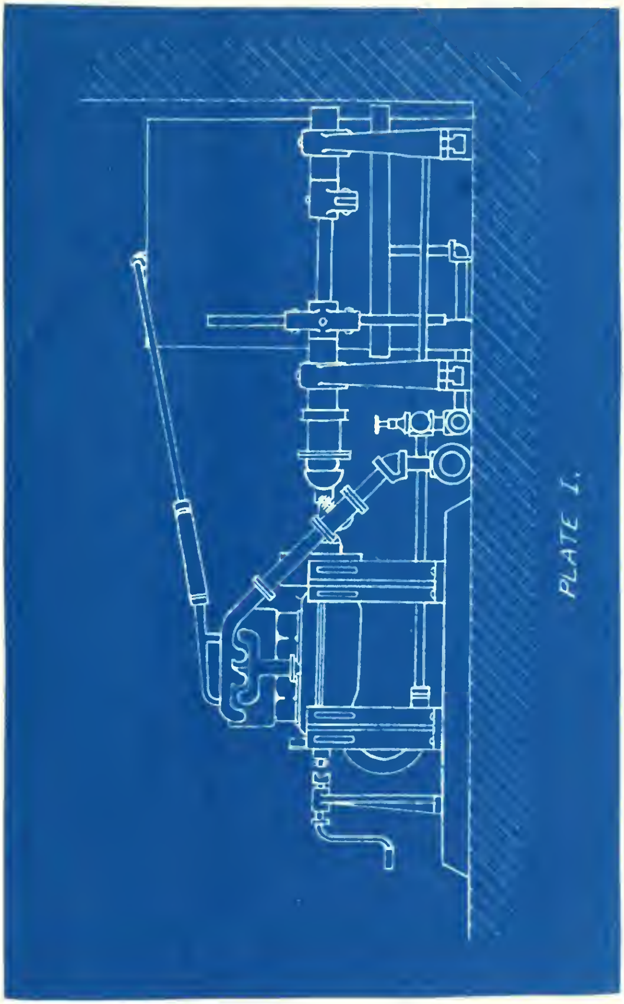


PLATE I.

The valves were located in cages in the cylinder heads and had an inner diameter of one and one quarter inches. They were actuated by rockers and push-rods from one gear driven cam-shaft. The inlet valves opened in the order, 1-3-4-2 which is the same of course as the order of firing.

Lubrication was by the constant level splash system, circulation being by a small gear pump thru a tell-tale glass.

Ignition was by means of a Splitdorf low-tension magneto and, batteries to be used for starting. This is known as the "dual" system since the breaker and distributer of the magneto and coil are used contimually whether the current comes from the magneto or ~~zzxx~~ battery. A variation of the spark from nine degrees late to twenty-five degrees early could be obtained.

Before any carburetor tests were attempted the motor was given a general overhauling and cleaned. The bearings were found to be tight and the whole engine in

very good condition. The valves were ground in and precaution was taken to see that the inlet valves had no play in their guides. On account of having ground the valves, it was necessary to adjust their tappets and then the events of the cycle were checked up in each cylinder. Quite a discrepancy was found in the results of the different cylinders, there being as much as fifteen degrees in one case. The average results were as follows:

Inlet opens:	8.5 degrees late
Inlet closes:	37.2 degrees late
Exhaust opens:	60.2 degrees early
Exhaust closes:	26.0 degrees late

For absorbing the power developed by this engine two different dynamometers were used, one of the fan type the other an electro-dynamometer. The former consisted simply of a frame, upon which a shaft was supported by two plain bearings. This shaft was connected to the engine crankshaft by two universal joints, the resistance being afford-

ed by two arms, mounted at right angles on the shaft; at the tips of these arms different sized blades could be attached, thus producing various load conditions. The electrodynamometer, sometimes called cradle dynamometer or electric brake, consisted of a direct current dynamo-motor mounted on a frame thru ball bearings and connected to the engine shaft by two universal joints. An arm, attached to the dynamo casing, indicated the torque by its pull on a spring balance. This arm was so proportioned that the product of the motor speed and scale reading divided by 1000 equalled the developed horse-power of the engine. Various loads were obtained by adjusting the field and armature currents. By this means any predetermined load could be thrown upon the engine.

There were two methods used in measuring the amount of fuel used. One was to supply the gasoline, thru a rubber hose, from a tank, supported on a scale which could be read to one half ounces; in this way the

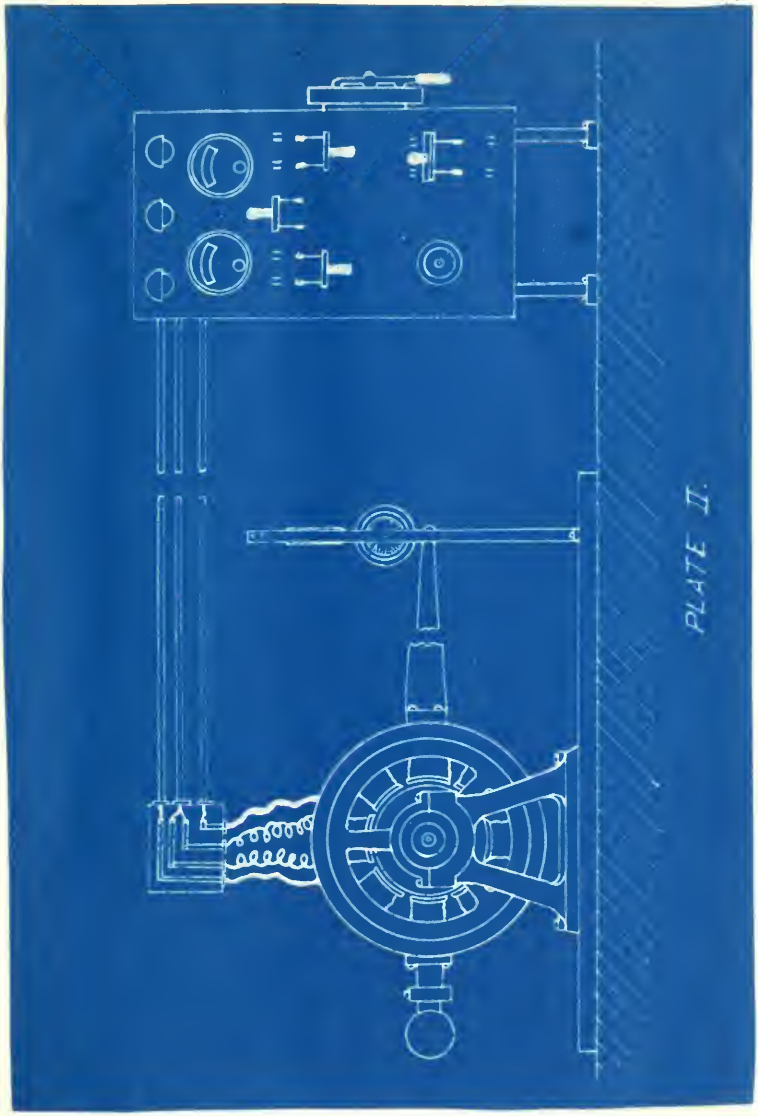


PLATE II.

direct weight of the liquid was obtained. The other method consisted in supplyimg the gasoline from a gallon tank, so fitted with a graduated glass, that readings were obtained to one one-thousandth of a gallon; then, knowing the specific gravity of the liquid at that particular temperature, its weight could be readily calculated.

The economy runs varied in length from one to five minutes, depending upon the rate of consumption and the speed of the motor. Thus in general: below 400 runs of four and five minutes were taken, from400 to 800 three minutes, from 800 to 1400 two minutes, above 1400, on account of the great speed, runs were never taken for longer than one minute. The amount of fuel consumed in runs of these durations, was great enough to give very accurate readings - within at least three or four percent of correct. In every case the time was taken by means of a stop watch, so practically no error arose from this measurement.

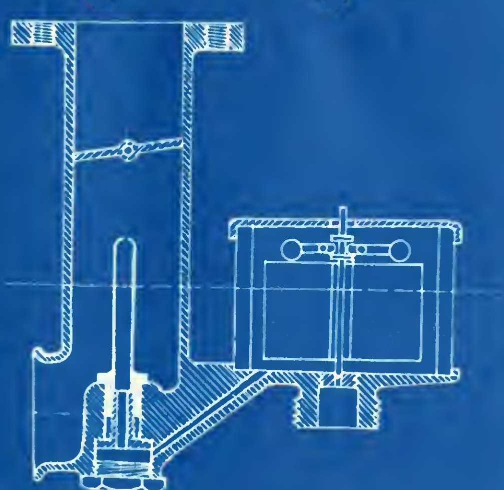
The speed of the motor was indicated by a tachometer which was belted to the dynamo shaft. This instrument was calibrated twice during the progress of the tests.

CARBURETOR "A_1".

This carburetor consisted of a straight tube, a two inch jet, in which the gasoline level was 5/8" below the tip, a constant air opening below the jet and at the side of the carburetor, a throttle valve, and a float chamber. The accompanying sketch shows the arrangement of these parts.

This extremely simple type of carburetor proved to be anything but satisfactory at medium and low speeds. When the motor was run at from 1100 to 1800 RPM. the horsepower and economy were very good; but to run the engine at low speeds it was necessary to restrict the air opening, this resulted in excessive gasoline consumption and loading in the manifold.

The best results from this carburetor were obtained when a #49 nozzle was used, the flexibility then being from 1200 to 1600, which of course shows this carburetor to be of no commercial value.



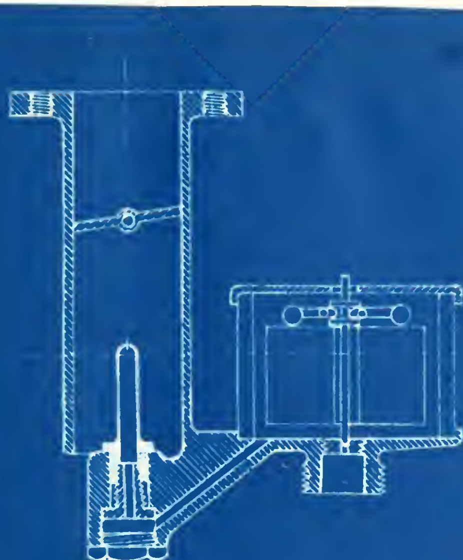
CARBURETOR A_1

CARBURETOR "A_2".

This carburetor was similar to "A_1" with the exception that the fixed air opening was placed directly below the jet, and a one and one-half inch nozzle used, in which the gasoline level was 1/8" below the tip.

By means of these changes the motor could be run at a considerably lower speed than was possible with the preceeding carburetor; the range of flexibility stayed about the same (350 RPM.) but, with a #42 nozzle, the speed was brought down to 950 RPM. This was evidently because the gasoline level was nearer the tip of the nozzle.

Very fair economy was obtained with this carburetor but on account of its speed limitations it was commercially valueless.



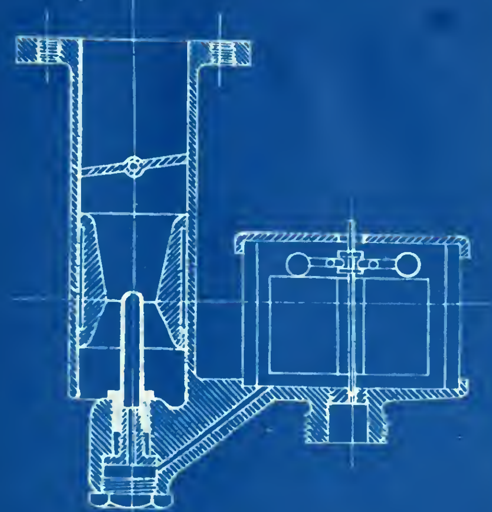
CARBURETOR A_2

CARBURETOR "B".

Obviously the next step to take in the building up of a perfect carburetor is to add some device which will produce greater flexibility. The Venturi tube seems almost ideal for this use in that it adds considerable flexibility without adding any complicated or moving parts.

In all, seven different sized Venturis were used the diameters at the throat being 17, 19, 20, 21, 22, 24, and 27 mm.; the 27 Venturi, however, was made with such a slight included angle (15 minutes) that no Venturi effect was produced, it only acting as a restriction of the throat. The included down stream angles of the other six Venturis were approximately 14 degrees while the upstream angles were found to be about twice this value.

As previously stated, the 27mm. Venturi was little more than a restriction in the tube, nevertheless, when using a #51 nozzle a flexibility of from 1575 to 900 RPM. was ob-



CARBURETOR B.

tained. This is an advantage over the straight tube carburetor, but economy runs brought out the fact that the former was much more wasteful of fuel than the latter; averaging about 1.2 pounds per horse-power hour, with the #51 nozzle.

The 24mm. Venturi was next used, this showed an increased flexibility and a slightly greater fuel consumptiom; with the #52 nozzle speeds of from 1550 tp 600 RPM. being obtained, the economy showing an average of 1.25 pounds per horse-power hour.

Then in order the 22, 21, 20, 19, and 17 mm. Venturis were tested, each with a number of different nozzles. These results are shown on accompanying pages and are self-explanatory.

CARBURETOR "C".

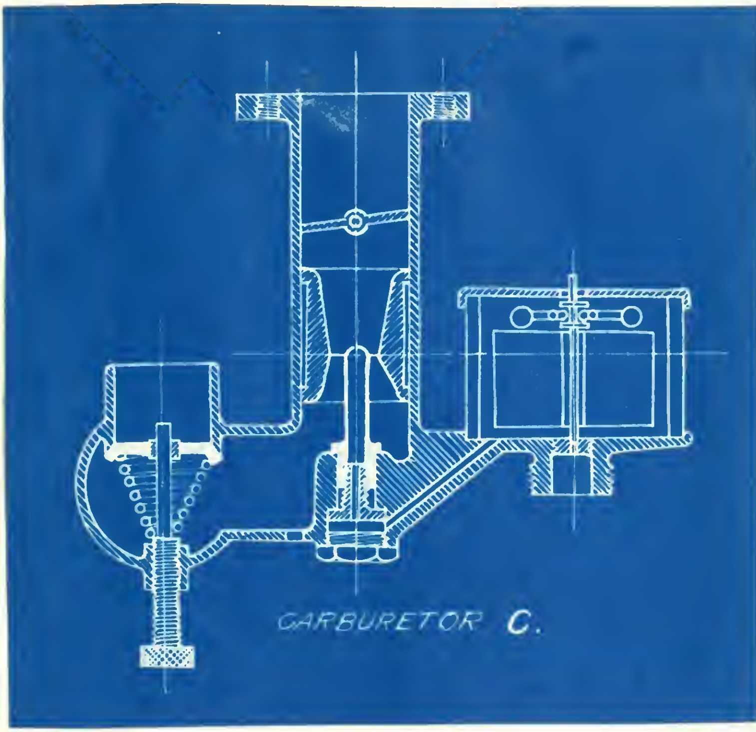
Carburetor "C" is identical in construction to carburetor "B" with the exception that a spring actuated auxiliary air valve was placed below the Venturi.

This carburetor proved, from the standpoint of good carburetion under various speeds, to be a failure. Since all of the air was taken thru the Venturi, its action at high speeds was necessarily the same as carburetor "B".

When using a 20 mm. Venturi and a #67 nozzle the conditions were about as follows:

350 - 1000	rich
1000 - 1300	lean
1300 - 1700	good

An analysis of the action of this carburetor established the fact that with a single nozzle and a constant Venturi, large enough to give maximum power, it was impossible to obtain good carburetion at all speeds.



CARBURETOR C.

For as the motor was throttled, less air than was required for the mixture was admitted in order to obtain a sufficient reduction in pressure at the nozzle. Low speed, then, was not obtained by any drop in pressure due to the throttling effect of the Venturi, but instead by restricting the air opening, thus maintaining the pressure drop in the entire carburetor chamber.

The large Venturi for high speeds, then, has no function at low speeds. Restricting the air opening in the above manner resulted in excessive loading in the manifold and an astonishingly high gasoline consumption.

CARBURETOR "D".

In the tests on carburetor "B" it will be noticed that as the size of the Venturi decreased the motor could be throttled to a lower speed and still give fair economy. Therefore in carburetor "D" a small Venturi was used in connection with an auxiliary air valve, placed above the Venturi, and controlled by a comparitively weak spring. When the motor was idling at low speeds all of the air passed thru the Venturi and by the nozzle. As the motor increased in speed the auxiliary air valve was opened, due to the greater reduction in pressure, and the rich mixture was diluted by this inrushing air.

The spring used in this carburetor was only suitable for low speeds; the range being from 150 to 1000 RPM. Above this latter speed the moxture became too weak to run the engine. One of the following curves, page 43, shows the economy and horse-power plotted against RPM. for this carburetor.

As in contrast with carburetor "B", carburetor "D" was primarily a low speed instrument. To obtain ~~a~~ high speed with it a stiff spring was substituted in place of the weak low speed spring.~~which had been formerly used.~~ This construction embodies carburetor "E".

CARBURETOR "E".

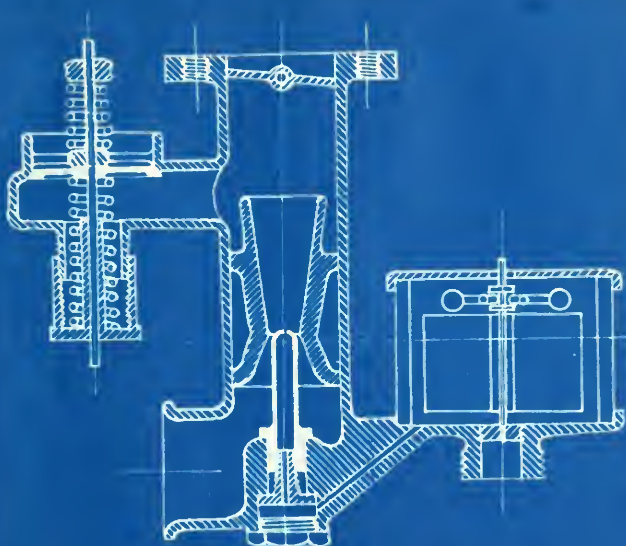
Carburetor "E" was, as expected, purely a high speed carburetor. Various springs were used until a range of from 900 to 1600 RPM. was obtained. Below 900 RPM. the auxiliary air valve hung off its seat weakening the charge to such an extent that it was impossible to obtain a good firing mixture

The curves show in graphical form the results of this test.

CARBURETOR "F".

In the construction of carburetor "F" the high speed spring and the low speed spring of the two preceeding carburetors were combined. This produced a good running mixture thruout the entire range of the motor.

In tuning up carburetor "F" the adjustments were made to give maximum power at approximately 1300 RPM., to run light at 200 RPM. , to accelerate well when the throttle was opened quickly, to give good economy at that speed at which the motor would more often run under actual conditions, and to attain all intermediate conditions under throttle and spark controll without backfires or noticable smoke from the exhaust. In short road conditions were approximated as nearly as possible.



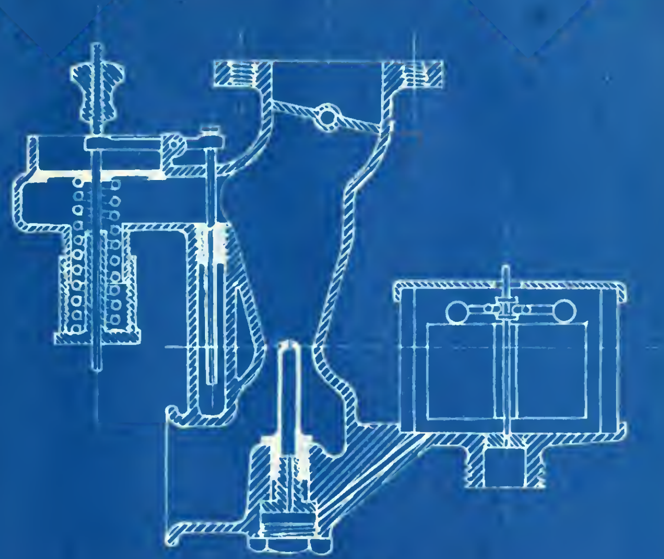
CARBURETOR F.

CARBURETOR "G".

Carburetor "G" differed in construction from carburetor "F" in that a secondary gasoline nozzle was used in place of a stiff high speed spring.

The action of this carburetor up to 900 RPM. was similar to the action of carburetor "F" up to the same speed. Above that, however, the secondary nozzle came into action and the mixture, which had been weakening, was strengthened by this added gasoline.

The adjustments on this carburetor were made as nearly as possible to approximate road conditions.



CARBURETOR G.

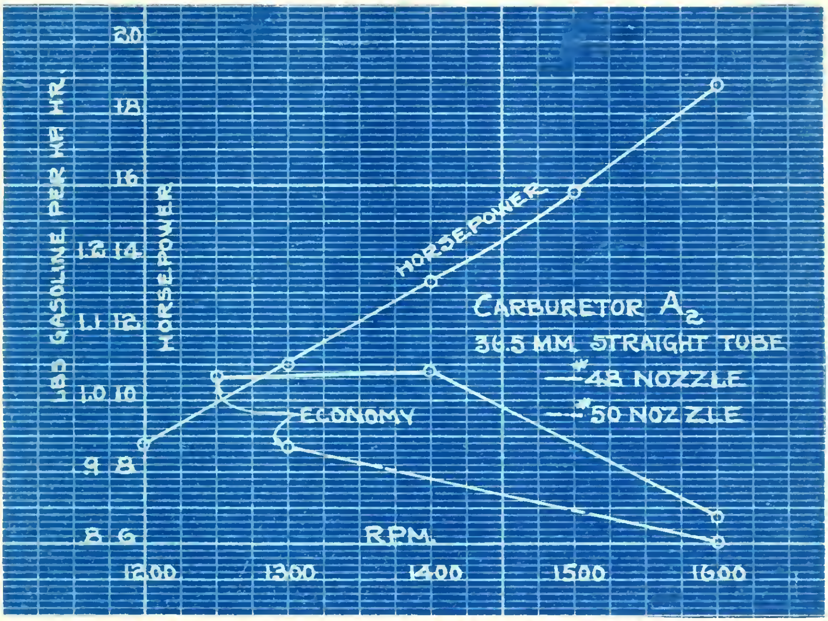
Discussion.

The results of all tests are given on the accompanying curve sheets. This method was chosen because it gives, at a glance a quick and concise method of comparison between the various carburetors. In most cases a smooth average curve was drawn thru the points.

As has been previously stated, all of these tests were made on a small Buick motor. Because of its size no great economy was obtained. This, however, was of small importance as the main object of these tests was to determine the principles of carburetion.

CARBURETOR "A_1".

One of the chief difficulties encountered in this carburetor was the extreme height of the nozzle. It required a considerable drop in pressure to pick up the gasoline with the level 5/8" below the tip of the jet. To obtain this drop in pressure it was necessary to run the motor at a ~~considerably~~ comparitively high speed. Another difficulty with this carburetor was the existance of eddy currents around the nozzle. This condition was revealed by a traverse, near the jet, with searching tubes; and was undoubtedly caused by the swirl of the inrushing air thru the opening in the side of the carburetor body.


LBS GASOLINE PER HP HR.
HORSEPOWER
20
18
16
1.2 14
1.1 12
1.0 10
.9 8
.8 6
HORSEPOWER
ECONOMY
CARBURETOR A2
36.5 MM STRAIGHT TUBE
#48 NOZZLE
#50 NOZZLE
RPM
1200
1300
1400
1500
1600

CARBURETOR "A_2".

To elliminate these eddy currents around the nozzle, carburetor "A_2" was made with the air opening in the bottom so that a straight flow past the nozzle was obtained.

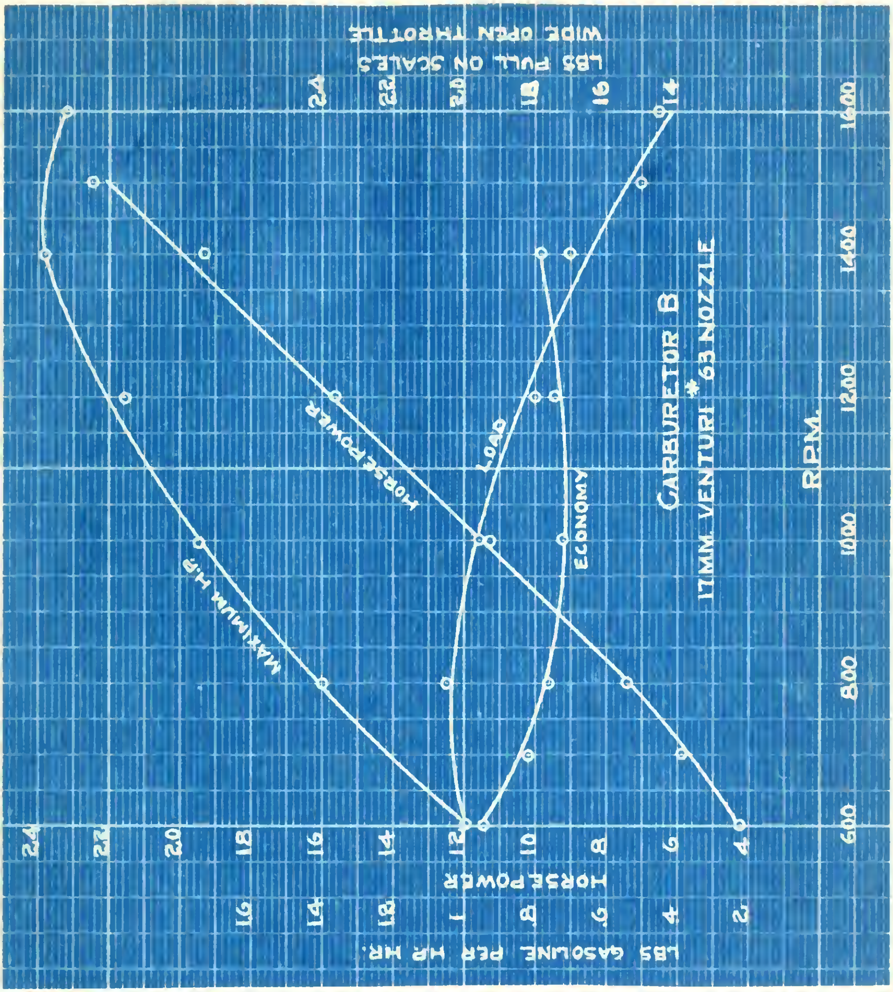
With the shorter nozzle, used in this carburetor a less reduction in pressure was required to pick up the gasoline thus permitting a lower engine speed.

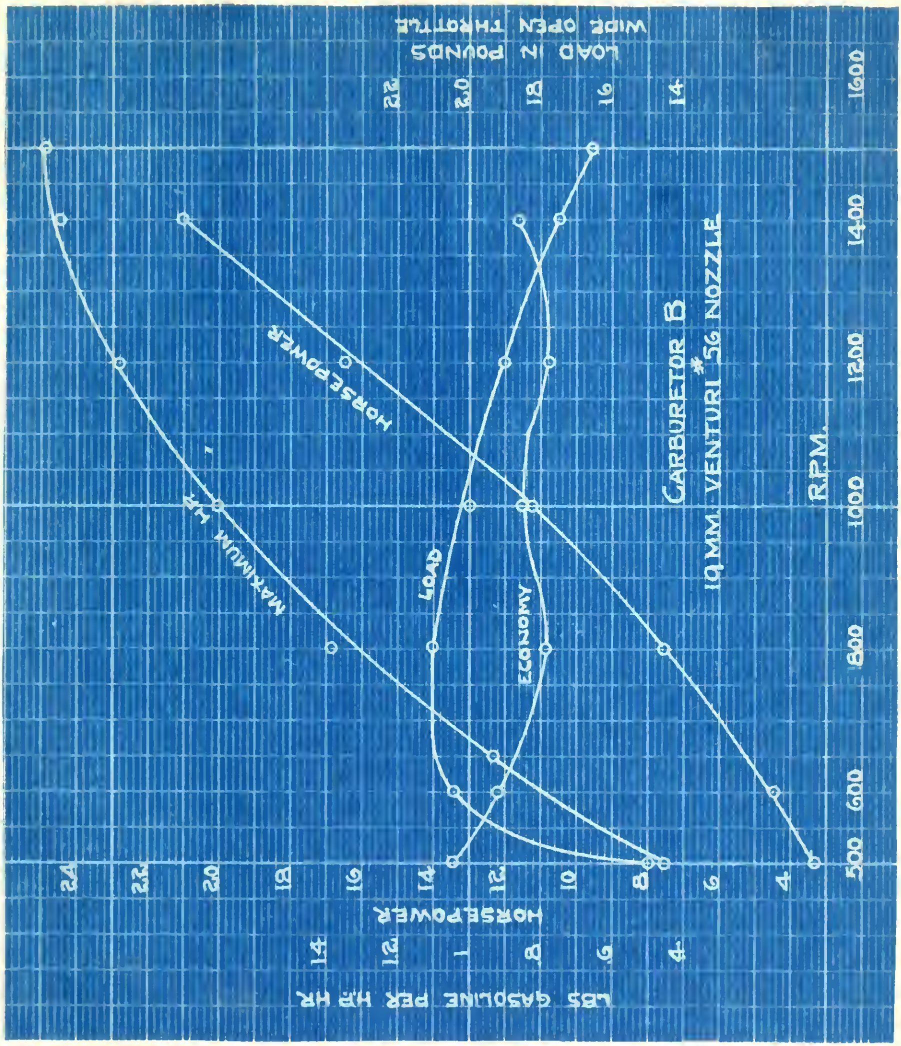
A study of the jets showed the natural angle of the gasoline, leaving the nozzle to be about fourteen degrees. The tendency at low speeds, that is low speeds for this carburetor, was for the gasoline to fall off against the sides of the carburetor and drip out of the bottom. Some means, then, was necessary to maintain a sufficient reduction in pressure around the nozzle to pick up the gasoline. A construction to accomplish this result embodies carburetor "B".

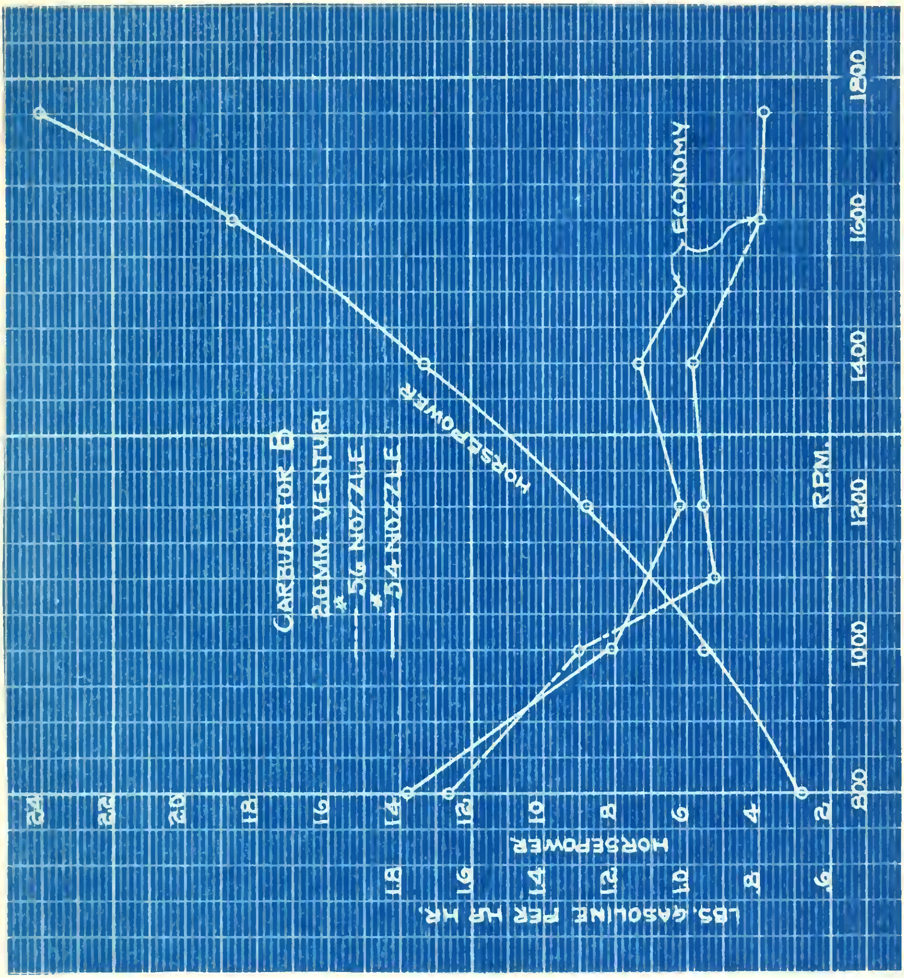
CARBURETOR "B".

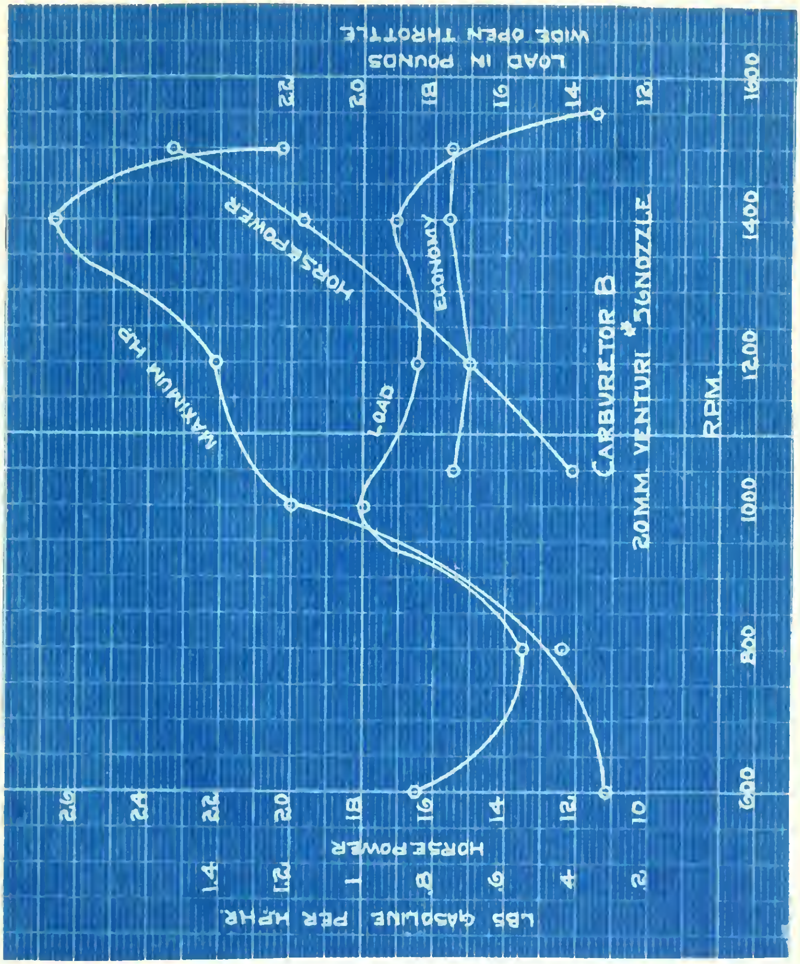
Venturis were made ranging from 17mm. to 27mm. in diameter with an included angle conforming to the shape of the jet, that is fourteen degrees. Each Venturi was placed in the tube so that the greatest reduction in pressure occurred at the tip of the nozzle.

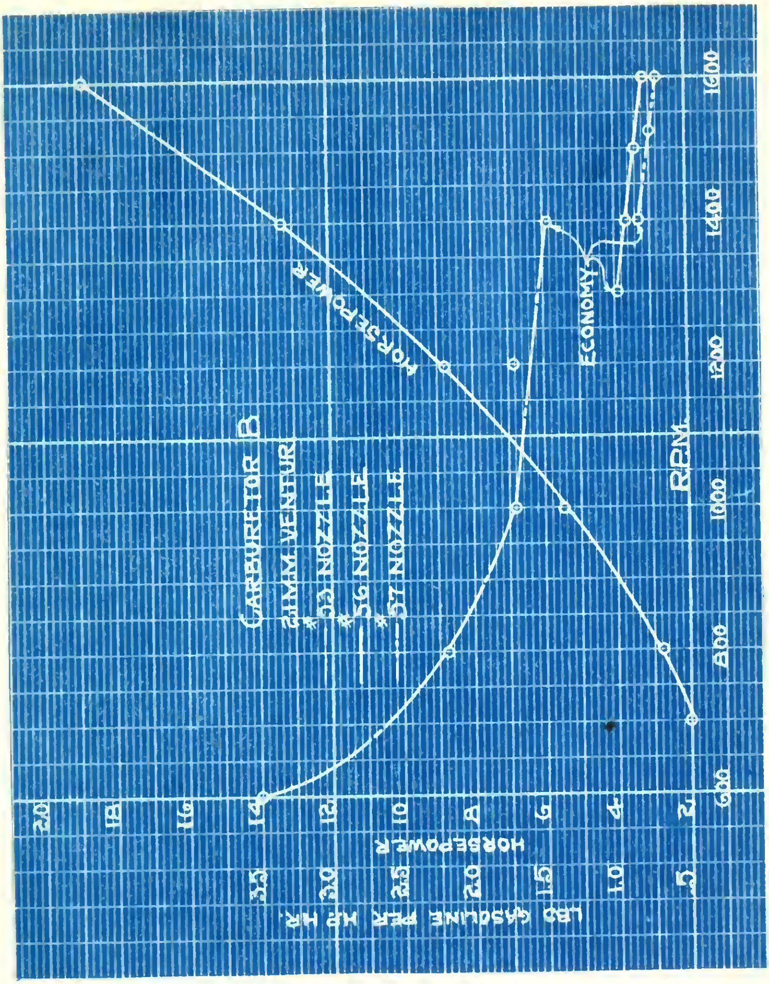
In general it was found that the smaller the Venturi the greater the flexibility. This statement, of course, is true within certain limits, for a marked decrease in the diameter of the Venturi sacrifices the maximum power obtainable. Low speed, then, cannot be obtained with a single nozzle, a constant Venturi, and a constant air opening suitable for high speeds.

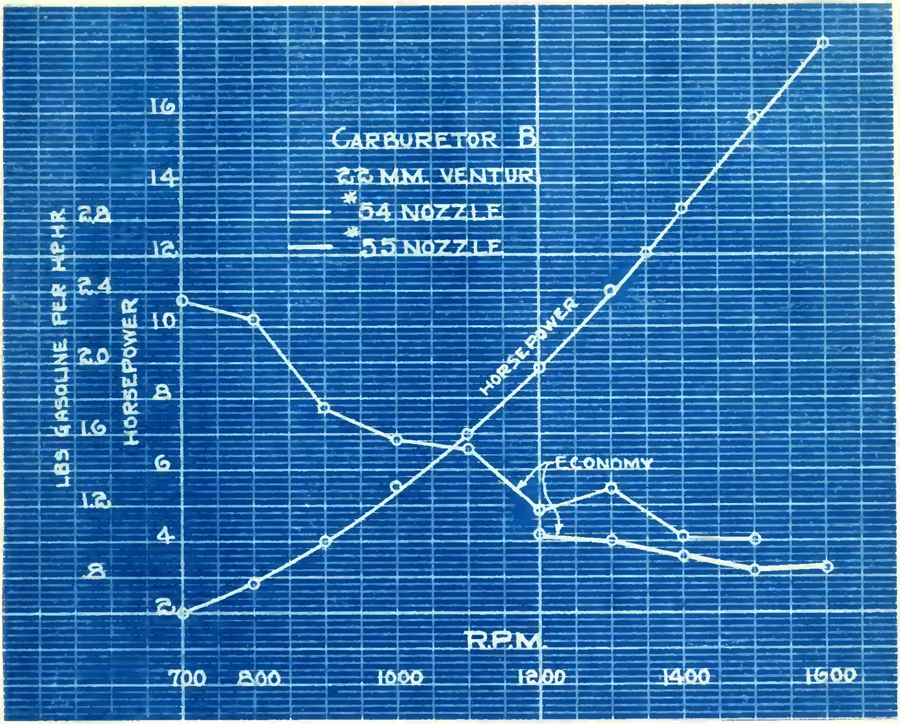

WIDE OPEN THROTTLE
LBS PULL ON SCALES
14 16 18 2.0 2.2 2.4
MAXIMUM HP
HORSEPOWER
LOAD
ECONOMY
CARBURETOR B
17MM. VENTURI * 63 NOZZLE
R.P.M.
600 800 1000 1200 1400 1600
HORSEPOWER
4 6 8 10 12 14 16 18 2.0 2.2 2.4
LBS GASOLINE PER HP HR.
.2 .4 .6 .8 1 1.2 1.4 1.6


WIDE OPEN THROTTLE
LOAD IN POUNDS
22
20
18
16
14
HORSEPOWER
MAXIMUM HP
LOAD
ECONOMY
CARBURETOR B
19 MM. VENTURI # 56 NOZZLE
R.P.M.
500
600
800
1000
1200
1400
1600
24
22
20
18
16
14
12
10
8
6
4
HORSEPOWER
1.4
1.2
1
.8
.6
.4
LBS GASOLINE PER HP HR


CARBURETOR B
20 MM VENTURI
56 NOZZLE
54 NOZZLE
HORSEPOWER
ECONOMY
R.P.M.
800
1000
1200
1400
1600
1800
HORSEPOWER
2
4
6
8
10
12
14
16
18
20
22
24
LBS. GASOLINE PER H.P. HR.
.6
.8
1.0
1.2
1.4
1.6
1.8

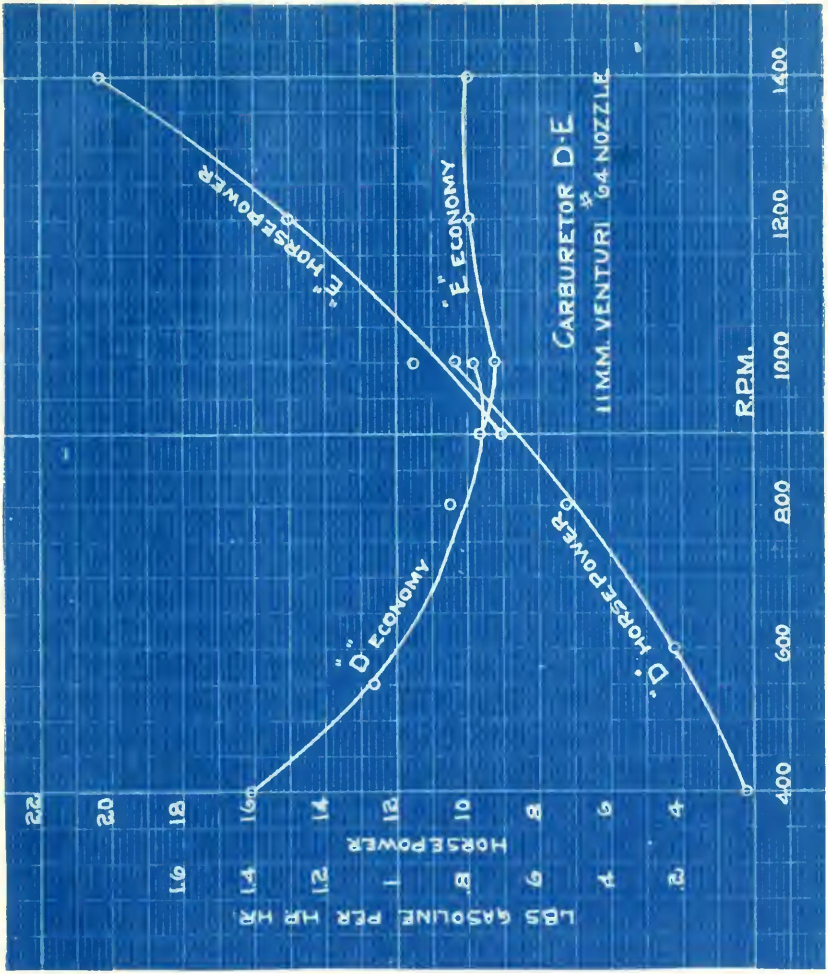

LOAD IN POUNDS
WIDE OPEN THROTTLE
22
20
18
16
14
12
HORSEPOWER
MAXIMUM HP
LOAD
ECONOMY
CARBURETOR B
20MM. VENTURI #56 NOZZLE
R.P.M.
600
800
1000
1200
1400
1600
26
24
22
20
18
16
14
12
10
1.4
1.2
1
.8
.6
.4
.2
LBS GASOLINE PER HP HR.

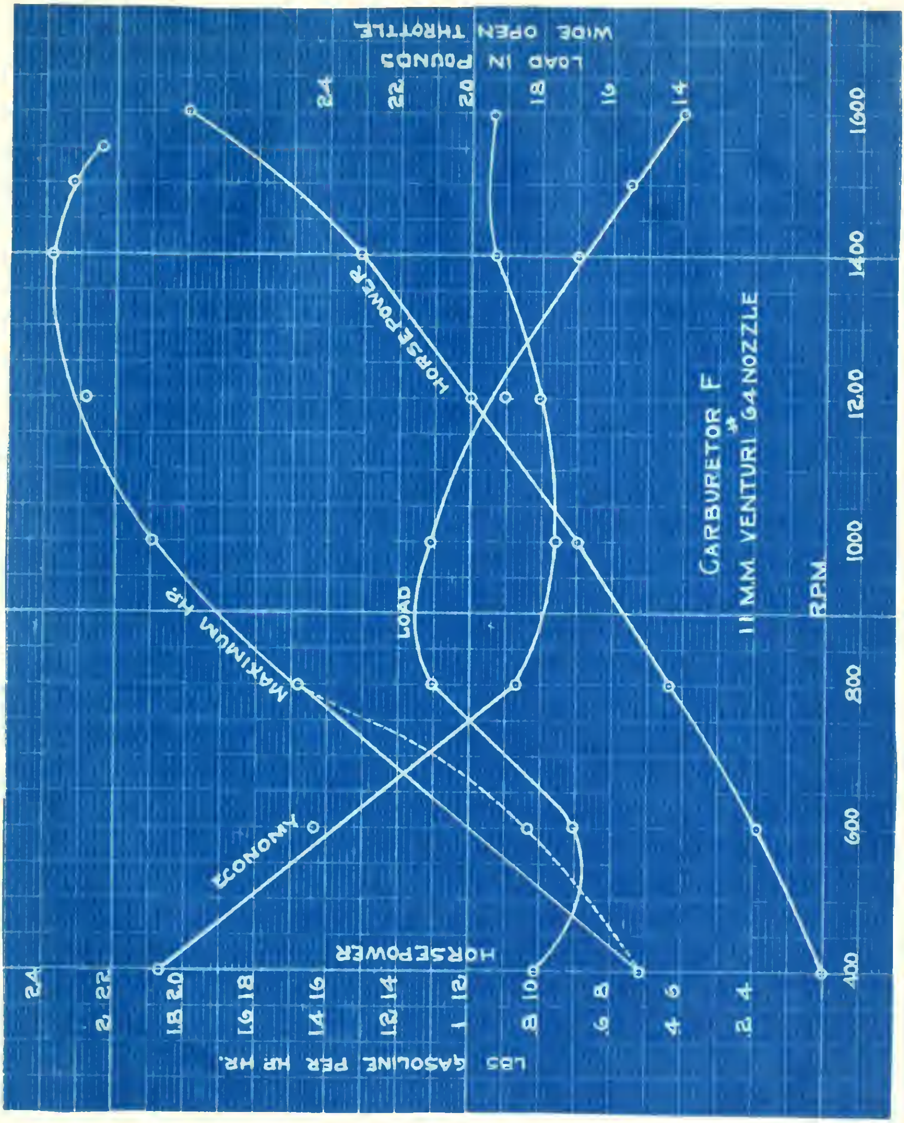

CARBURETOR B
21 MM. VENTURI
53 NOZZLE
56 NOZZLE
57 NOZZLE
HORSEPOWER
ECONOMY
R.P.M.
HORSEPOWER
LBS GASOLINE PER HP HR.
600
800
1000
1200
1400
1600
2
4
6
8
10
12
14
16
18
20
.5
1.0
1.5
2.0
2.5
3.0
3.5

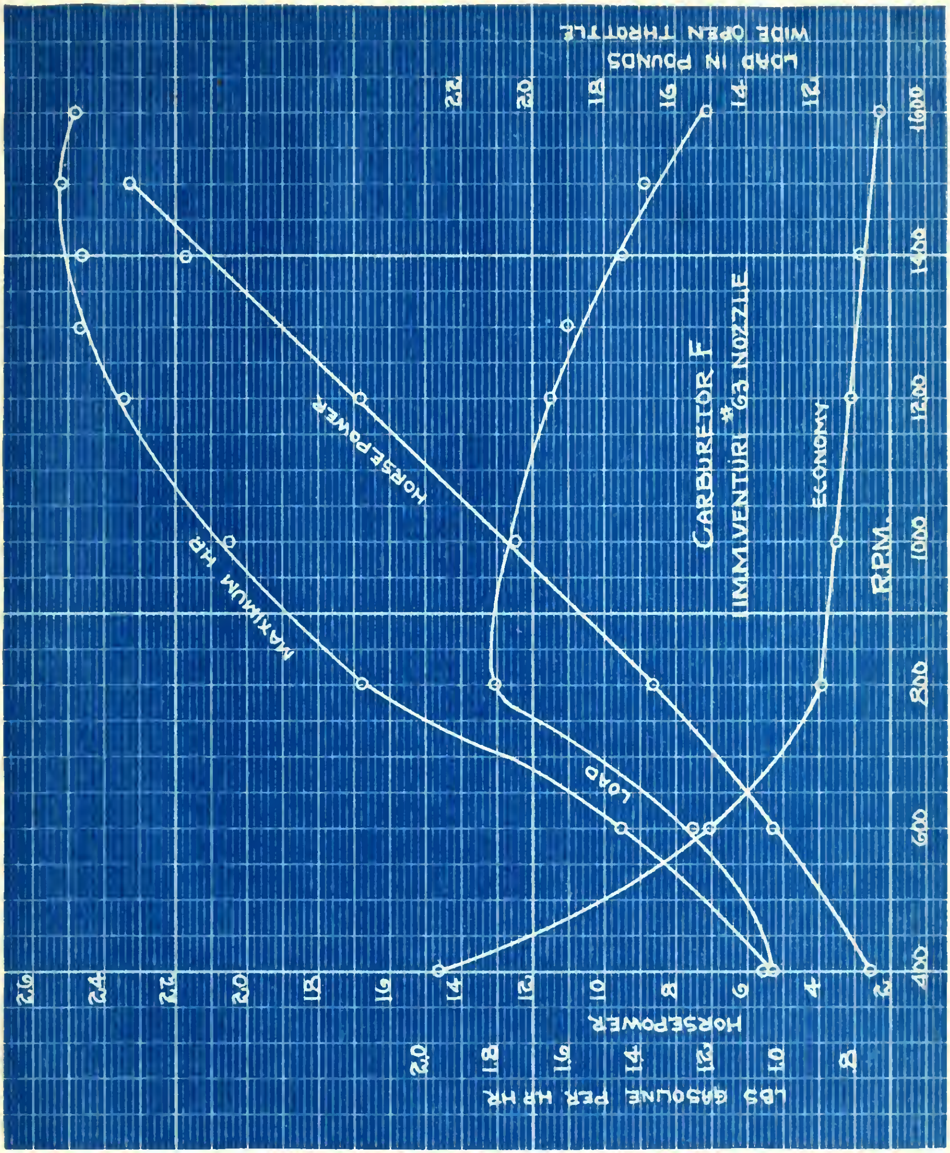

CARBURETOR B
22 MM. VENTURI
*54 NOZZLE
*55 NOZZLE
LBS GASOLINE PER HP HR
HORSEPOWER
HORSEPOWER
ECONOMY
R.P.M.
700
800
1000
1200
1400
1600
16
14
12
10
8
6
4
2
2.8
2.4
2.0
1.6
1.2
.8

CARBURETOR "F".

This carburetor was constructed with the idea of overcoming the faults of carburetor "B", spoken of last. A small Venturi gave low speed, and air, admitted above the Venturi, diluted the rich mixture at high speeds. This type of carburetor using a #63 nozzle, as indicated on the curve, page 45 , had a larger auxiliary air opening than the one using a #64 nozzle, curve, page 44 . This accounts for the increase in power of the former over the latter.

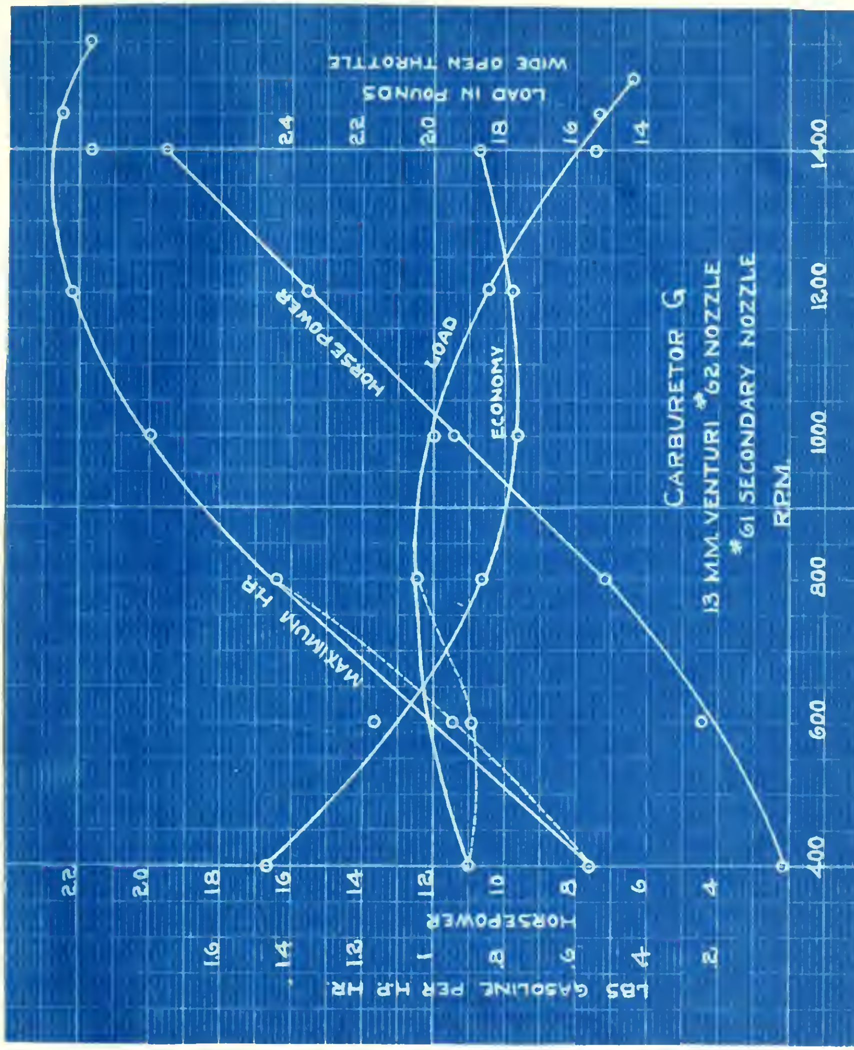

CARBURETOR D-E
11 MM. VENTURI #64 NOZZLE
"E" HORSEPOWER
"E" ECONOMY
"D" ECONOMY
"D" HORSEPOWER
R.P.M.
400
600
800
1000
1200
1400
HORSEPOWER
22
20
18
16
14
12
10
8
6
4
LBS GASOLINE PER HP HR
1.6
1.4
1.2
1
.8
.6
.4
.2


CARBURETOR F
11 M.M. VENTURI #64 NOZZLE
WIDE OPEN THROTTLE
LOAD IN POUNDS
HORSEPOWER
LBS GASOLINE PER HP HR.
MAXIMUM HP
ECONOMY
LOAD
HORSEPOWER
RPM
400
600
800
1000
1200
1400
1600


WIDE OPEN THROTTLE
LOAD IN POUNDS
CARBURETOR F
1MM VENTURI #63 NOZZLE
ECONOMY
R.P.M.
HORSEPOWER
MAXIMUM HP
LOAD
HORSEPOWER
LBS GASOLINE PER HP HR

CARBURETOR "G".

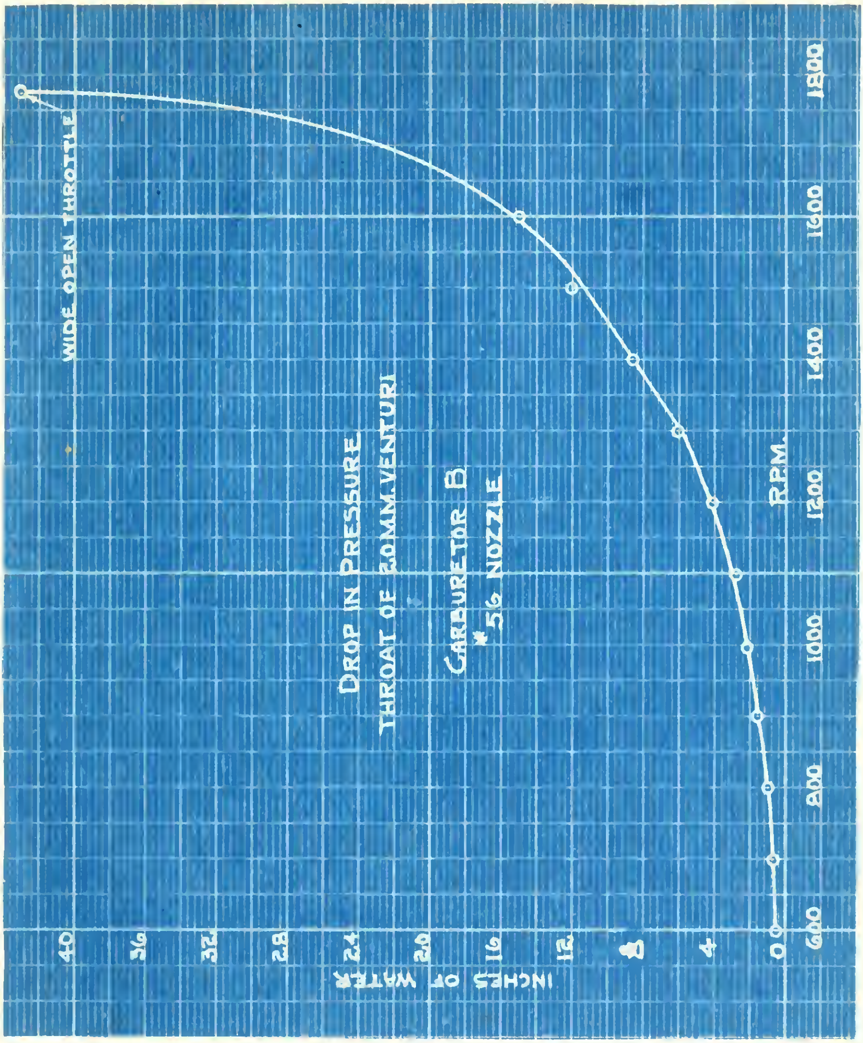
The action of this carburetor differs from the preceeding one in that at high speeds a secondary gasoline nozzle comes into action. This form of carburetor is applicable, partiscularly, to large motors and is, therefore, not economical when working on as small a motor as was used in this test. The graphical results of this carburetor show a decreasing economy until the secondary nozzle came into action, from there on the economy rises slightly.

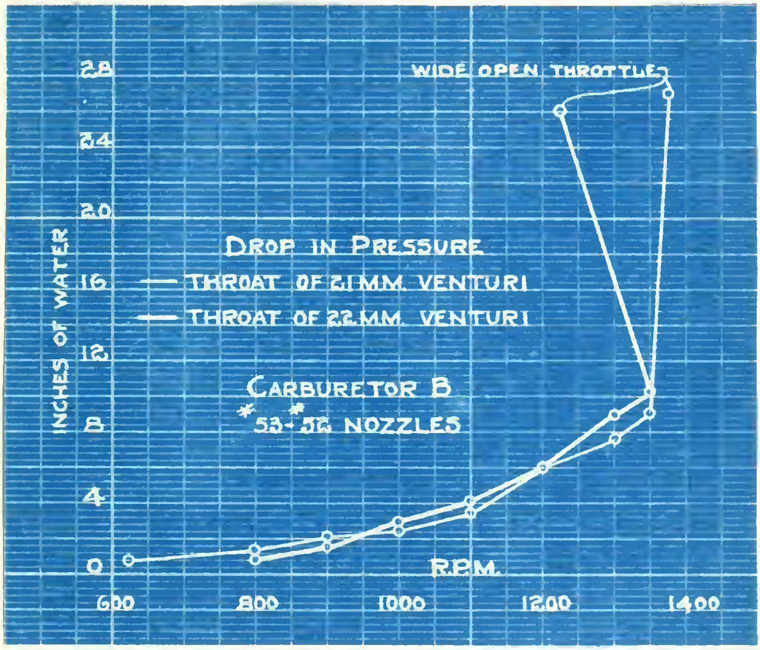

WIDE OPEN THROTTLE
LOAD IN POUNDS
HORSE POWER
LOAD
ECONOMY
MAXIMUM H.P.
CARBURETOR G
13 MM. VENTURI #62 NOZZLE
#61 SECONDARY NOZZLE
R.P.M.
HORSEPOWER
LBS GASOLINE PER H.P. HR.

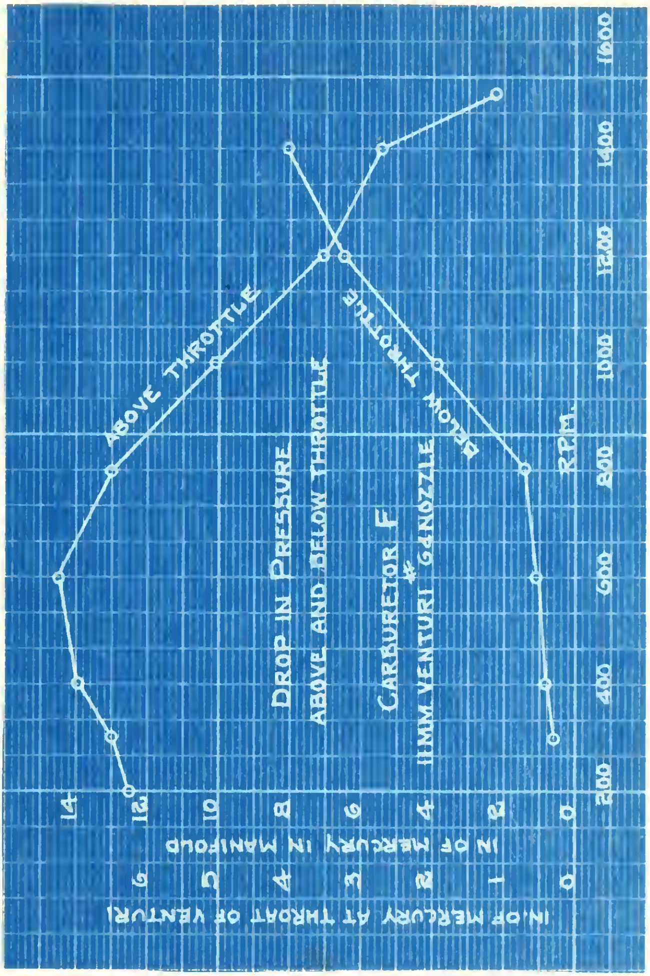
In order to obtain some idea of the pressures existing inside of a carburetor, above and below the throttle, several tests were made; the results of which are shown on the three succeeding pages.

In obtaining this data two ordinary U-tubes were used, one filled with mercury for high vacuums, the other with water for the lower pressure values. The searching tube consisted simply of a tapered glass nozzle. Experiments were made with more theoretically shaped tubes but no appreciable difference in the readings could be seen, therefore the simplest form was adopted.

In all these tests the motor was run under its own power, thus the throttle opening was a direct function of the speed.


DROP IN PRESSURE
THROAT OF 20 MM. VENTURI
CARBURETOR B
#56 NOZZLE
WIDE OPEN THROTTLE
RPM.
600
800
1000
1200
1400
1600
1800
INCHES OF WATER
0
4
8
12
16
20
24
28
32
36
40


WIDE OPEN THROTTLE
DROP IN PRESSURE
THROAT OF 21 MM. VENTURI
THROAT OF 22 MM. VENTURI
CARBURETOR B
#53-#52 NOZZLES
INCHES OF WATER
R.P.M.
0
4
8
12
16
20
24
28
600
800
1000
1200
1400


DROP IN PRESSURE
ABOVE AND BELOW THROTTLE
CARBURETOR F
#
11MM VENTURI 64 NOZZLE
ABOVE THROTTLE
BELOW THROTTLE
R.P.M.
200 400 600 800 1000 1200 1400 1600
IN. OF MERCURY IN MANIFOLD
0 2 4 6 8 10 12 14
IN. OF MERCURY AT THROAT OF VENTURI
0 1 2 3 4 5 6

Conclusion.

The growing tendency in carburetor construction of today is to eliminate all movable and adjustable parts. It is desired to have a carburetor as simple in construction as "B" , but with the flexibility and acceleration of "F" and "G".

The conditions in "B" were approximately:

11 mm. Venturi, range(200-550RPM.)
economy .85 pounds per H.P.

15 mm. Venturi, range (500-1100)
economy .75 pounds per H.P.

20 mm. Venturi, range (1000-1700)
economy .7 pounds per H.P.

These results seem to indicate the practibility of constructing a carburetor having three Venturi tubes and three nozzles arranged in such a manner that they would be brought into action as the motor increased

in speed. Lack of time, however, prohibited the building of such a carburetor for test purposes.

It is the belief of the writers of this thesis that a three Venturi carburetor, as described above, would be simple, economical, and absolutely free from adjustments.